

CLEAN VERSION OF AMENDMENTS

In the Specification:

*Replace the paragraph starting on Page 1, line 6, with:*

MS BA  
a1  
The present application is a continuation of pending Application No. 09/433,657 filed 11/3/99 on behalf of Rosenberg et al., which is a continuation of Application No. 08/664,086, filed June 14, 1996, now Patent No. 6,028,593, which is a continuation-in-part of U.S. Patent Application Nos. 08/566,282, filed December 1, 1995, now Patent No. 5,734,373; and 08/571,606, filed December 13, 1995, now Patent No. 6,219,032; and where said Application No. 08/664,086 claims the benefit of provisional application No. 60/017,803, filed May 17, 1996, all of which are incorporated herein by reference for all purposes.

*Replace the paragraph starting on Page 9, line 30, with:*

a2  
User object 34 is preferably coupled to sensors 28 and actuators 30 by a mechanical apparatus which provides a number of degrees of freedom to the user object. Such a mechanical apparatus can take a variety of forms, from a simple rotary joint or linear coupling allowing a single degree of freedom, to a complex mechanical linkage allowing multiple degrees of freedom to the user object. Examples of mechanical apparatuses are described in Patent Nos. 5,576,727; 5,731,804; 5,767,839; 5,721,566; and 5,805,140, all of which are hereby incorporated by reference herein. Preferred embodiments of mechanical apparatuses suitable for sporting simulations disclosed herein are described subsequently with reference to Figures 14-18.

*Replace the paragraph starting on Page 11, line 3, with:*

a3  
In the described embodiment, host computer system 12 implements a host application program with which a user 22 is interacting via peripherals and interface device 14. For example, the host application program can be a video game, medical simulation, scientific analysis program, or even an operating system or other application program that can utilize force feedback. Typically, the host application provides images to be displayed on a display output device, as described below, and/or other feedback, such as auditory signals. For example, a graphical user interface for an operating system is described in greater detail in Patent No. 6,219,032, which is hereby incorporated by reference herein.

*Replace the paragraph starting on Page 13, line 3, with:*

a4  
The present embodiment is that low-bandwidth serial communication signals can be used to interface with interface device 14, thus allowing a user to directly use a standard built-in serial interface of many low-cost computers. Alternatively, a parallel port of host computer system 12 can be coupled to a parallel bus 24 and communicate with interface device using a parallel protocol, such as SCSI or PC Parallel Printer Bus. In a different embodiment, bus 24 can be connected directly to a data bus of host computer system 12 using, for example, a plug-in card and slot or other access of computer system 12. For example, on an IBM AT compatible computer, the interface card can be implemented as an ISA, EISA, VESA local bus, PCI, or other well-known standard interface card. Other types of interfaces 14 can be used with other computer systems. In another embodiment, an additional bus 25 can be included to communicate between host computer system 12 and interface device 14. Since the speed requirement for communication signals is relatively high for outputting force feedback signals, a single serial interface used with bus 24 may not provide signals to and from the interface device at a high enough rate to achieve realistic force feedback. Bus 24 can thus be coupled to the standard serial port of host computer 12, while an additional bus 25 can be coupled to a second port of the host computer system, such as a "game port" or other port. The two buses 24 and 25 can be used simultaneously to provide an increased data bandwidth. Such an embodiment is described in greater detail in Patent No. 5,691,898, which is hereby incorporated by reference herein.

*Replace the paragraph starting on Page 17, line 4, with:*

a5  
Other types of interface circuitry 36 can also be used. For example, an electronic interface is described in U.S. Patent No. 5,576,727, assigned to the same assignee as the present application, and which is hereby incorporated by reference herein. The interface allows the position of the mouse or stylus to be tracked and provides force feedback to the stylus using sensors and actuators. Sensor interface 36 can include angle determining chips to pre-process angle signals reads from sensors 28 before sending them to the microprocessor 26. For example, a data bus plus chip-enable lines allow any of the angle determining chips to communicate with the microprocessor. A configuration without angle-determining chips is most applicable in an embodiment having absolute sensors, which have output signals directly indicating the angles without any further processing, thereby requiring less computation for the microprocessor 26 and thus little if any pre-processing. If the sensors 28 are relative sensors, which indicate only the

a5  
concl.

change in an angle and which require further processing for complete determination of the angle, then angle-determining chips are more appropriate.

Replace the paragraph starting on Page 18, line 28, with:

ab

Power supply 40 can optionally be coupled to actuator interface 38 and/or actuators 30 to provide electrical power. Active actuators typically require a separate power source to be driven. Power supply 40 can be included within the housing of interface device 14, or can be provided as a separate component, for example, connected by an electrical power cord. Alternatively, if the USB or a similar communication protocol is used, interface device 14 can draw power from the bus 24 and thus have no need for power supply 40. Such an embodiment is described in greater detail in Patent No. 5,691,898.

Replace the paragraph starting on Page 19, line 4, with:

at the time

Safety switch 41 can be included in interface device 14 to provide a mechanism to allow a user to override and deactivate actuators 30, or require a user to activate actuators 30, for safety reasons. Certain types of actuators, especially active actuators such as motors, can pose a safety issue for the user if the actuators unexpectedly move user object 34 against the user with a strong force. In addition, if a failure in the control system 10 occurs, the user may desire to quickly deactivate the actuators to avoid any injury. To provide this option, safety switch 41 is coupled to actuators 30. In one embodiment, the user must continually activate or close safety switch 41 during operation of interface device 14 to activate the actuators 30. If, at any time, the safety switch is deactivated (opened), power from power supply 40 is cut to actuators 30 (or the actuators are otherwise deactivated) as long as the safety switch is deactivated. Examples of safety switches are described in Patent No. 5,691,898.

Replace the paragraph starting on Page 22, line 31, with:

a8

For example, a kinematic equation which calculates a force based on the velocity of the user object multiplied by a damping constant can be used to determine a damping force on the user object. This type of equation can simulate motion of object 34 along one degree of freedom through a fluid or similar material. A procedure for calculating a damping force on object 34 is described in Patent No. 5,767,839, which is hereby incorporated by reference herein. For example, a damping constant can first be selected which indicates the degree of resistance that

98  
concl.

object 34 experiences when moving through a simulated material, such as a liquid, where a greater number indicates greater resistance. For example, water would have a lower damping constant than oil or syrup. The host computer recalls the previous position of user object 34 (along a particular degree of freedom), examine the current position of the user object, and calculate the difference in position. From the sign (negative or positive) of the difference, the direction of the movement of object 34 can also be determined. The force is then set equal to the damping constant multiplied by the change in position. Commands that controlled an actuator based on this algorithm would produce a force proportional to the user object's motion to simulate movement through a fluid. Movement in other mediums, such as on a bumpy surface, on an inclined plane, etc., can be simulated in a similar fashion using different methods of calculating the force.

99  
100  
101  
102  
103  
104  
105  
106  
107  
108  
109  
110  
111  
112  
113  
114  
115  
116  
117  
118  
119  
120  
121  
122  
123  
124  
125  
126  
127  
128  
129  
130  
131  
132  
133  
134  
135  
136  
137  
138  
139  
140  
141  
142  
143  
144  
145  
146  
147  
148  
149  
150  
151  
152  
153  
154  
155  
156  
157  
158  
159  
160  
161  
162  
163  
164  
165  
166  
167  
168  
169  
170  
171  
172  
173  
174  
175  
176  
177  
178  
179  
180  
181  
182  
183  
184  
185  
186  
187  
188  
189  
190  
191  
192  
193  
194  
195  
196  
197  
198  
199  
200  
201  
202  
203  
204  
205  
206  
207  
208  
209  
210  
211  
212  
213  
214  
215  
216  
217  
218  
219  
220  
221  
222  
223  
224  
225  
226  
227  
228  
229  
230  
231  
232  
233  
234  
235  
236  
237  
238  
239  
240  
241  
242  
243  
244  
245  
246  
247  
248  
249  
250  
251  
252  
253  
254  
255  
256  
257  
258  
259  
260  
261  
262  
263  
264  
265  
266  
267  
268  
269  
270  
271  
272  
273  
274  
275  
276  
277  
278  
279  
280  
281  
282  
283  
284  
285  
286  
287  
288  
289  
290  
291  
292  
293  
294  
295  
296  
297  
298  
299  
300  
301  
302  
303  
304  
305  
306  
307  
308  
309  
310  
311  
312  
313  
314  
315  
316  
317  
318  
319  
320  
321  
322  
323  
324  
325  
326  
327  
328  
329  
330  
331  
332  
333  
334  
335  
336  
337  
338  
339  
340  
341  
342  
343  
344  
345  
346  
347  
348  
349  
350  
351  
352  
353  
354  
355  
356  
357  
358  
359  
360  
361  
362  
363  
364  
365  
366  
367  
368  
369  
370  
371  
372  
373  
374  
375  
376  
377  
378  
379  
380  
381  
382  
383  
384  
385  
386  
387  
388  
389  
390  
391  
392  
393  
394  
395  
396  
397  
398  
399  
400  
401  
402  
403  
404  
405  
406  
407  
408  
409  
410  
411  
412  
413  
414  
415  
416  
417  
418  
419  
420  
421  
422  
423  
424  
425  
426  
427  
428  
429  
430  
431  
432  
433  
434  
435  
436  
437  
438  
439  
440  
441  
442  
443  
444  
445  
446  
447  
448  
449  
450  
451  
452  
453  
454  
455  
456  
457  
458  
459  
460  
461  
462  
463  
464  
465  
466  
467  
468  
469  
470  
471  
472  
473  
474  
475  
476  
477  
478  
479  
480  
481  
482  
483  
484  
485  
486  
487  
488  
489  
490  
491  
492  
493  
494  
495  
496  
497  
498  
499  
500  
501  
502  
503  
504  
505  
506  
507  
508  
509  
510  
511  
512  
513  
514  
515  
516  
517  
518  
519  
520  
521  
522  
523  
524  
525  
526  
527  
528  
529  
530  
531  
532  
533  
534  
535  
536  
537  
538  
539  
540  
541  
542  
543  
544  
545  
546  
547  
548  
549  
550  
551  
552  
553  
554  
555  
556  
557  
558  
559  
560  
561  
562  
563  
564  
565  
566  
567  
568  
569  
570  
571  
572  
573  
574  
575  
576  
577  
578  
579  
580  
581  
582  
583  
584  
585  
586  
587  
588  
589  
590  
591  
592  
593  
594  
595  
596  
597  
598  
599  
600  
601  
602  
603  
604  
605  
606  
607  
608  
609  
610  
611  
612  
613  
614  
615  
616  
617  
618  
619  
620  
621  
622  
623  
624  
625  
626  
627  
628  
629  
630  
631  
632  
633  
634  
635  
636  
637  
638  
639  
640  
641  
642  
643  
644  
645  
646  
647  
648  
649  
650  
651  
652  
653  
654  
655  
656  
657  
658  
659  
660  
661  
662  
663  
664  
665  
666  
667  
668  
669  
670  
671  
672  
673  
674  
675  
676  
677  
678  
679  
680  
681  
682  
683  
684  
685  
686  
687  
688  
689  
690  
691  
692  
693  
694  
695  
696  
697  
698  
699  
700  
701  
702  
703  
704  
705  
706  
707  
708  
709  
710  
711  
712  
713  
714  
715  
716  
717  
718  
719  
720  
721  
722  
723  
724  
725  
726  
727  
728  
729  
730  
731  
732  
733  
734  
735  
736  
737  
738  
739  
740  
741  
742  
743  
744  
745  
746  
747  
748  
749  
750  
751  
752  
753  
754  
755  
756  
757  
758  
759  
760  
761  
762  
763  
764  
765  
766  
767  
768  
769  
770  
771  
772  
773  
774  
775  
776  
777  
778  
779  
780  
781  
782  
783  
784  
785  
786  
787  
788  
789  
790  
791  
792  
793  
794  
795  
796  
797  
798  
799  
800  
801  
802  
803  
804  
805  
806  
807  
808  
809  
810  
811  
812  
813  
814  
815  
816  
817  
818  
819  
820  
821  
822  
823  
824  
825  
826  
827  
828  
829  
830  
831  
832  
833  
834  
835  
836  
837  
838  
839  
840  
841  
842  
843  
844  
845  
846  
847  
848  
849  
850  
851  
852  
853  
854  
855  
856  
857  
858  
859  
860  
861  
862  
863  
864  
865  
866  
867  
868  
869  
870  
871  
872  
873  
874  
875  
876  
877  
878  
879  
880  
881  
882  
883  
884  
885  
886  
887  
888  
889  
890  
891  
892  
893  
894  
895  
896  
897  
898  
899  
900  
901  
902  
903  
904  
905  
906  
907  
908  
909  
910  
911  
912  
913  
914  
915  
916  
917  
918  
919  
920  
921  
922  
923  
924  
925  
926  
927  
928  
929  
930  
931  
932  
933  
934  
935  
936  
937  
938  
939  
940  
941  
942  
943  
944  
945  
946  
947  
948  
949  
950  
951  
952  
953  
954  
955  
956  
957  
958  
959  
960  
961  
962  
963  
964  
965  
966  
967  
968  
969  
970  
971  
972  
973  
974  
975  
976  
977  
978  
979  
980  
981  
982  
983  
984  
985  
986  
987  
988  
989  
990  
991  
992  
993  
994  
995  
996  
997  
998  
999  
1000

*Replace the paragraph starting on Page 26, line 23, with:*

In an alternate embodiment having host computer 12 directly control force feedback, a local microprocessor 26 (as shown in Figure 2) can be included in interface device 14 to assist in relaying sensor and actuator data to and from the host and for commanding forces to be output as long as there is no change in forces. This type of embodiment is not a "reflex" embodiment as described in Figure 4 since forces output by interface device 14 are dependent on active and continuous control from the host computer. Such an embodiment is described in greater detail in Patent Nos. 5,739,811 and 5,734,373, both incorporated by reference herein. For example, in step 80 above, the host computer can check if there is a change in force required on user object 34 depending on the above-described parameters. If not, then the host need not issue a low-level command, since local microprocessor could continue to issue the previous low-level command. The local microprocessor 26 can also convert a low-level command to an appropriate form before it is sent to actuators 30.

*Replace the paragraph starting on Page 27, line 28, with:*

210

The process of Figure 4 is suitable for low speed communication interfaces, such as a standard RS-232 serial interface. However, the embodiment of Figure 4 is also suitable for high speed communication interfaces such as USB, since the local microprocessor relieves computational burden from host processor 16. In addition, this embodiment can provide a straightforward command protocol, an example of which is described with respect to Patent No.

a10  
encl.

5,734,373, incorporated by reference herein, and which allows software developers to easily provide force feedback in a host application.

---

*Replace the paragraph starting on Page 30, line 1, with:*

---

a10  
encl.

If no change in the type of force is currently required in step 110, then the process returns to step 106 to update the host application and return to step 110 to again check until such a change the type of force is required. When such a change is required, step 112 is implemented, in which host computer 12 determines an appropriate host command to send to microprocessor 26. The available host commands for host computer 12 can correspond to an associated force routine implemented by microprocessor 26. For example, different host commands to provide a damping force, a spring force, a gravitational pull, a bumpy surface force, a virtual obstruction force, and other forces can be available to host computer 12. These host commands can also include a designation of the particular actuators 30 and/or degrees of freedom which are to apply this desired force on object 34. The host commands can also include other command parameter information which might vary the force produced by a particular force routine. For example, a damping constant can be included in a host command to designate a desired amount of damping force, or a direction of force can be provided. The host command may also preferably override the reflex operation of the processor 26 and include low-level force commands directly sent to actuators 30. A preferred command protocol and detailed description of a set of host commands is described in Patent No. 5,734,373. These commands can include direct host commands, "reflex" commands, and custom effects. Each direct host command preferably includes parameters which help the host specify the characteristics of the desired output force and may include a specified force routine. "Reflex" commands, in contrast, provide conditions to the microprocessor so that the desired force is output when the conditions are met, such as when a specified button is pressed by the user. Custom effects can be provided to the microprocessor 26 by the host and then commanded to be output. For example, the host computer can download to the microprocessor a set of force values (a force profile) as a "force profile file" or other collection of data using a host command `LOAD_PROFILE`; a separate host command `PLAY_PROFILE` could then be sent to instruct the microprocessor to output the downloaded force profile as forces on user object 34, or when a condition occurs, etc. For example, a force profile file can include an array of force values, size information about the size of the data, and timing information for when to output the various force values.

---

*Replace the paragraph starting on Page 30, line 1, with:*

a12 Embodiments using a local microprocessor 26 to implement reflex processes is described by Patent Nos. 5,739,811 and 5,734,373, both assigned to the assignee of this present application, and both hereby incorporated by reference herein.

*Replace the paragraph starting on Page 40, line 4, with:*

a13  
FIG. 6a-6h  
FIG. 6a-6h show how paddle object 220 interacts with a moving ball object 206 as ball object 206 collides with the paddle object. In Figure 6a, ball 206 first impacts paddle 220. Preferably, an initial force is applied to user object 34 in the appropriate (corresponding) direction of the ball's movement. In Figures 6b and 6c, ball 206 is moving into the compliant paddle or "sling." Preferably, a force based on a simulated mass of ball 206 (and/or other simulated conditions) is felt by the user through user object 34 which is appropriate to the simulated velocity of the ball (and/or the paddle), the simulated compliance of the paddle (and/or the ball), and the strength and direction of simulated gravity. In a local microprocessor embodiment, as described in Figure 4, these factors (and other desired physical factors) can preferably be set using a host command with the appropriate parameters, as described in Patent No. 6,219,032. For example, parameters of objects can be specified and simulated such as mass of the ball, velocity of the ball, the strength of gravity, the direction of gravity, the compliance or stiffness of the paddle object 220, damping forces to the collision between the ball and paddle, a simulated mass of the paddle 220, and other parameters to control other physical aspects of the computer environment and interaction of objects. In addition, the ball 206 can be displayed as a compressed object when it impacts paddle 220, with, for example, an oval or elliptical shape. Also, the parameters such as the compliance and/or damping of the paddle might be allowed to be adjusted by the user with other input 39 or an additional degree of freedom of a user object 34 manipulated by the user.

N.E.

(NOT in line)

*Replace the paragraph starting on Page 40, line 4, with:*

N.E. An interface apparatus providing two linear (X and Y) degrees of freedom to user object 34 as well as a rotating ("spin") third degree of freedom about a Z axis is quite suitable for the paddle-ball implementation. Linear degree of freedom apparatuses are disclosed in Patent Nos. 5,721,566 and 5,805,140, previously incorporated herein, and further embodiments of such are described below.